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This paper describes the Intelligent Gateway/Scaleable Simulation (IGSS) project created to perform research into problems associated with large-scale simulations, combining both real and simulated units on Local Area Networks (LANS) and Wide Area Networks (WANs). The program's goal is to achieve seamless simulation by providing worldwide access to multilayer simultaneous, realtime, very large virtual warfighting environments composed of 10,000 or more objects. Seamless simulation requires user-friendly, self-configuring, variable-scale environments with essential resolution, and transparent connectivity. The IGSS program's intent to research areas of potential difficulty resulted in the selection of the following subprojects: (1) Integration of highly dynamic live objects with synthetic objects; (2) interoperability of coarse grain (e.g., time step wargames/aggregate units) with fine grain (realtime/individuals units) simulations; (3) interoperability of engineering fidelity simulators with moderate fidelity simulators; and (4) networking of large numbers of objects (10,000 to 100,000) into one simulated warfighting environment.

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CONNECTIVITY FOR THE HIGHLY DYNAMIC VEHICLES IN A REAL AND SYNTHETIC ENVIRONMENT (HYDY) PROJECT

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INTRODUCTION

The Advanced Research Projects Agency (ARPA) has created the Intelligent Gateway/Scaleable Simulation (IGSS) project to perform research into problems associated with large-scale simulations, combining both real and simulated units on Local Area Networks (LANs) and Wide Area Networks (WANs). The program's goal is to achieve seamless simulation by providing worldwide access to multi-layer simultaneous, realtime, very large virtual warfighting environments composed of 10,000 or more objects. Seamless simulation requires user-friendly, self-configuring, variable-scale environments with essential resolution, and transparent connectivity. The IGSS program's intent to research areas of potential difficulty resulted in the selection of the following subprojects: (1) Integration of highly dynamic live objects with synthetic objects; (2) interoperability of coarse grain (e.g., time step wargames/aggregate units) with fine grain (realtime/individual units) simulations; (3) interoperability of engineering fidelity simulators with moderate fidelity simulators; and (4) networking of large numbers of objects (10,000 to 100,000) into one simulated warfighting environment.

An Advanced Interface Unit (AIU) will be developed to provide capabilities/tools for simulators and real systems to use in interfacing with the warfighting network.

This effort, called Highly Dynamic Vehicles (HYDY), Phase I, resulted in a Proof-of-Concept (POC) demonstration showing the feasibility of integrating a live F–14D aircraft into the simulation environment. Network connectivity was established between (1) an existing aircraft simulation facility located at the Naval Air Warfare Center Aircraft Division (NAWCAD) Manned Flight Simulator (MFS) in Patuxent River, MD; (2) the Naval Air Warfare Center Weapons Division (NAWCWD) System Integration Test Station (SITS) in Pt. Mugu, CA; and (3) the Secure Integration Simulation Laboratory (SISL) located at the Naval Command, Control and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation (RDT&E) Division in San Diego, CA.

OVERVIEW

This paper provides a general discussion of the effort to connect the three facilities (MFS, SITS, SISL), the modification made to those facilities to support this project, the connectivity established between and within the facilities, problems encountered, lessons learned, and the results of the HYDY Phase I POC demonstration.

The culmination of this effort will allow a live aircraft, while in flight, to interact Beyond Visual Range (BVR) with simulated aircraft (e.g., man simulators). This interaction will result from stimulation of the aircraft's radar and Radar Warning Receiver (RWR) based on an interchange of information between the simulated unit(s) and the live aircraft. The interchange will use ground communication of Protocol Data Units (PDUs) formatted in accordance with the Simulation Training and Instrumentation Command (STRICOM)/ARPA draft military standard for a Distributed Interactive Simulation (DIS) protocol and radio frequency (RF) communication using the "express PDUs." Based on information received in the PDUs, the radar and RWR will be stimulated. For this demonstration DIS PDUs were transmitted via ground-based communications facilities at the three sites specified above.

This effort demonstrated the ability to utilize DIS standard PDUs with HYDY vehicles (DIS entities) over a LAN and WAN by using one (or two) of these DIS entities to stimulate an active radar (APG–71) that was simultaneously receiving real aircraft returns. The challenge was to stimulate the radar such that the real and simulated returns were indistinguishable from each other.

FACILITY AND HARDWARE DESCRIPTIONS

Systems Integration Test Station (SITS)

The SITS facility develops, tests, integrates, verifies, and validates flight software for the F–14D fighter aircraft and provides a ground-based site for development and test of modifications required to allow injection of simulated air targets into the radar for display on cockpit display consoles. SITS contains the front section of an F–14D with all of the operational flight computers, the complete radar system, and a full cockpit. This partial airframe's

location allows the radar to be turned on and detect real aircraft flying on the NAWCWD test range. A Radar Target Stimulator (RTS) allows the injection of computer-generated targets into the radar system while detecting live targets on the range. Therefore, a live F–14D radar could be stimulated from a simulation network by modification of the RTS system, which would cause it to accept DIS PDUs as definitions of the targets it should inject into the F–14D radar system. The software is described in a later section.

SITS hardware connectivity starts with a local Navy Network (NAVNET) node (T1 tail circuit). NAVNET is a long haul T1 (1.544-million-bits-per-second [MBPS]) network with nodes located at various sites. The local NAVNET node feeds a 56-thousand-bits-per-second (KBPS) tail circuit into the SITS facility. The hardware connection inside the facility, from modem to F–14D airframe, is described in the following paragraphs.

Network Hardware Connectivity. Network connectivity consists of the following equipment required to bring the DIS PDUs to/from the AIU:

(1) A Codex 2172 Modem configured to operate at 56 KBPS connects the NAVNET tail circuit to a KG–84A.

(2) A KG–84A point–to–point data cryptographic device connects to the modem by a V.35 to RS–422 cable and a RS–422 to MIL–STD–188C Minimate connector. The V.35 connects to the modem while the MIL–STD–188C connects to the "Black" (encrypted) connection on the KG–84A.

(3) A TIMEPLEX Minilink unit provides the link between "phone" and computer communications. This unit is connected to the KG–84A "Red" (decrypted) connection by an MIL–STD–188C to RS–422 Minimate connector and a RS–422 to RS–422 cable.

(4) A RAD REB–10 ethernet bridge provides for a dedicated thick ethernet line to the AIU. This unit is connected to the Minilink via an RS–422 cable.

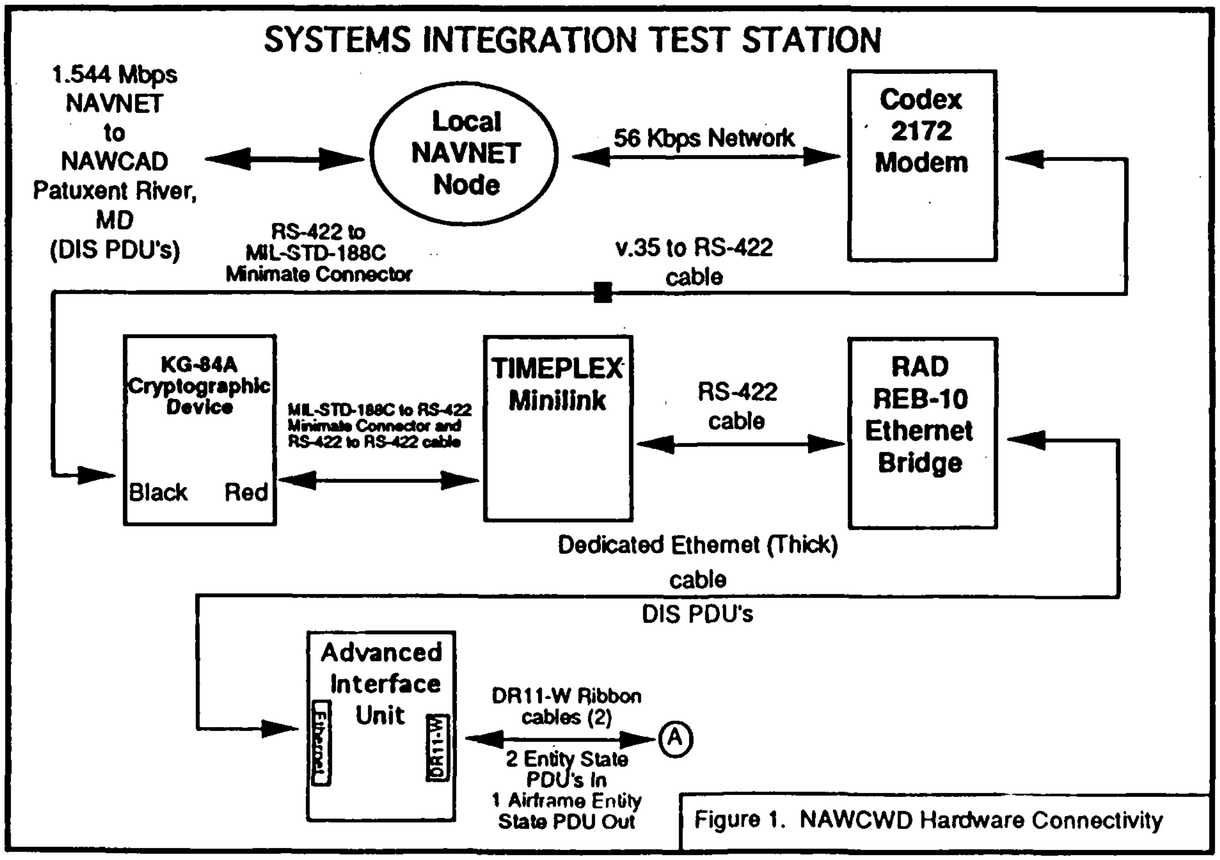

Figure 1. NAWCWD Hardware Connectivity

AIU Hardware Connectivity. The AIU is responsible for the network interface, the managing of DIS PDUs and the interface to the host, a VAX 8600 described in the next section. The AIU consists of a Force CPU-40 processor board and an Icron DR11-W emulator board, both residing in a VME card cage. The AIU is connected to the ethernet bridge via a thick ethernet cable. The DR11-W is connected to the VAX 8600 by two 16-pin flat ribbon cables; one for input and one for output of data.

The AIU also provides a simple PDU generation feature that allows the operator to cause the device to output PDUs to itself and to the network that represents an aircraft. This aircraft can be maneuvered interactively by the operator.

Radar Target Simulator Hardware Connectivity. The RTS hardware connectivity includes a VAX-8600 Interfacing Unit, the RTS system, and Airframe Interfacing Unit. These three "units" are described as follows:

(1) The VAX 8600 provides the interface between the AIU, RTS and the F-14D airframe. Thus,the AIU receives local entity data from the F-14D airframe interface and provides the RTS with the target entity data received from the network via the AIU. The VAX converts state information from DIS world coordinates to latitude and longitude and vice versa, compares the target/frame aspect ratios to generate target Radar Cross Sections (RCS), and formats RCS packet data to be sent to the RTS. It communicates with the AIU and the airframe interface via a DR11-W interface and with the RTS by "thin" ethernet. Each DR11-W interface requires two 16-pin flat ribbon cables.

(2) The RTS primarily consists of a Hewlett Packard HP-1000, a target generator chassis, RF and intermediate frequency (IF) interfaces, electronic countermeasures (ECM) equipment, and an IBM 386 personal computer for front-end operator interaction and display. The RTS provides for radar/target simulations and various electronics for IF link injection into the airframe radar. The front end for simulation control has a graphics display of what the radar sees. The RTS is connected via ethernet to the VAX 8600 and to the F-14D airframe via MIL-STD-1553B cables (to the radar bus) and IF link.

(3) The airframe interface consisting of a Force CPU-40 processor, an Icron DR11-W emulator, and a 1553B bus interface board all residing in a VME card cage. This unit provides airframe state vector and orientation data to the VAX-8600. The DR11-W interface connects to the VAX-8600 via the two 16-pin flat ribbon cables and the 1553 bus interface connects to the airframe.

F-14D Airframe/Test Management Station H/W Connectivity

(1) The Test Management Station (TMS) is the "software pilot" that "flies" the F-14D airframe. The TMS provides the airframe equipment with all the dynamic flight data necessary to indicate in flight conditions. The TMS is connected to the airframe via MIL-STD-1553B cables (to the mission computer and radar buses) and various discrete connections.

(2) The F-14D airframe platform receives "flight" data and characteristics from the TMS and radar target data from the RTS. This is an actual F-14D cockpit with all required equipment for radar operations and analysis.

Equipment Present for Demonstration. For the purposes of the demonstration, the following nonstandard equipment (in addition to the AIU) was connected to the ethernet network that provided the interface between the REB-10 and the AIU.

(1) The Technologies System Inc. (TSI) Low Cost Stealth was connected to provide for both two- and three-dimensional displays of the simulated world as represented by the PDUs received over the network. This includes PDUs generated to report the position of the SITS airframe (pseudo live aircraft) and any simulation entities being reported on the network.

(2) The SIMULIZER was connected to provide a scripted "target" generation capability. The SIMULIZER would output a scripted set of DIS PDUs on command that represented one or more aircraft flying a predetermined route.

Manned Flight Simulator

The MFS facility's mission is to provide, through simulation, test and evaluation (T&E) of aircraft and onboard aircraft avionics systems and pilot training. The MFS includes high-fidelity flight-dynamics system simulation, avionics system simulators, a wide field-of-view (FOV) visual system for man-in-the-loop evaluations, and a motion-base system to provide acceleration cues for conventional takeoff and landing tasks as well as vertical and short takeoff and landing, hover, and transition. The MFS incorporates four simulation stations: the motion base, the dome, the laboratory station, and the crew station which includes the F-14 back seat, the F/A-18, and the V-22 Government Test Pilot Trainer. A COMPU-SCENE IV Visual Image Generator (VIG)

system and an IRIS visual system provide high- and medium-resolution visuals. In addition, the dome FOV simulator provides two projectors for target generation.

The dome with an F/A–18 and one target generator was used for this POC demonstration. The simulation program at MFS was modified to accept DIS PDUs for target generation and to output DIS PDUs from the simulation platform. The software is described in a later section.

NAWCAD hardware connectivity starts with a local NAVNET node (T1 tail circuit). The local NAVNET node feeds a 56-KBPS tail circuit into the MFS facility. From inside the facility, the hardware connection from modem to cockpit simulator is described in the following paragraphs.

Network H/W Connectivity. Network connectivity consists of all the following equipment required to bring the DIS PDUs to/from the AIU.

(1) A TYTEK Modem configured to operate at 56 KBPS connects the NAVNET tail circuit to KG–84As.

(2) Two KG–84A point-to-point data cryptographic devices connect to the two modems by RS–449 to RS–449 cable and RS–422 to MIL–STD–188C Minimate connector. The RS–499 connects to the modem while the MIL–STD–188C connects to the "black" (encrypted) connection on the KG–84A. Two KG–84As are needed as one is connected to SITS and the other is connected to SISL.

(3) A TIMEPLEX Minilink unit provides the link between "phone" and computer communications. This unit is connected to the KG–84A on the "red" (decrypted) connection by a MIL–STD–188C to RS–422 Minimate connector and from the Minimate to the Minilink by a RS–449 to Minilink tempest cable.

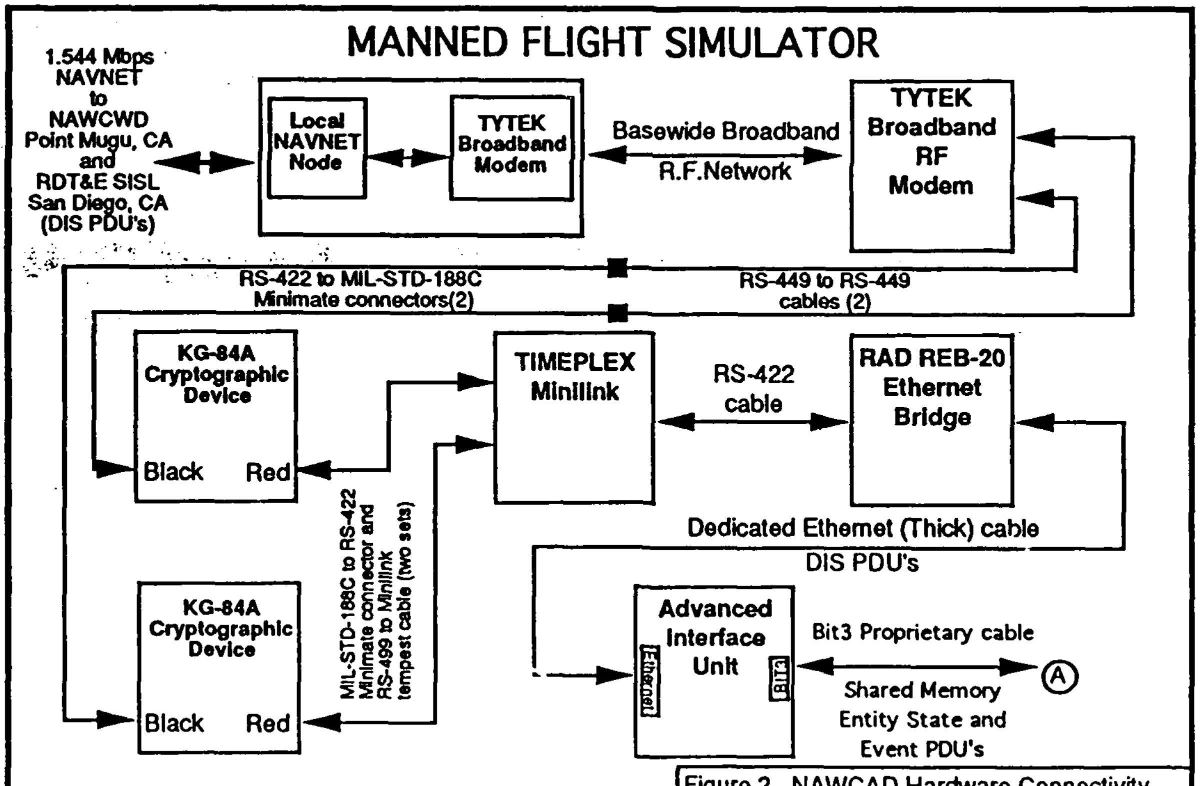

Figure 2. NAWCAD Hardware Connectivity

(4) A RAD REB–20 Ethernet Bridge will pass ethernet packets to and from each of the NAV-NET connections and provide for a dedicated thick ethernet line to the AIU. This unit is connected to the Minilink via an RS–422 cable.

AIU H/W Connectivity. The AIU is responsible for the network interface, the managing of DIS PDUs, and the interface to the Host, a Digital Equipment Corporation (DEC) Micro VAX II. The AIU consists of a Force CPU–40 processor board and a Bit3 Qbus-to-VME adapter board with 8-Mbytes of dual-port RAM, both residing in a VME card cage. The Bit3 card allows the CPU–40 and a Micro VAX to share one Mbyte of RAM. The AIU is connected to the RAD REB–20 Ethernet Bridge via a thick ethernet cable. The Bit3 card is connected to the Micro VAX II by the Bit3 supplied flat ribbon cables; one for input and one for output of data.

Cockpit Simulator H/W Connectivity. The cockpit simulator consists of

(1) Micro VAX (uVax) providing the AIU "host" processes. This process manages the transfer of DIS PDUs between the AIU and multiport memory. The uVAX contains the Qbus side of the Bit3 Qbus-to-VME Adapter to the AIU.

(2) uVax dedicated for avionic simulations. The F/A–18 avionics models duplicate the functions performed by the actual avionics in the aircraft. The avionics models simulate the AYK–14 mission computers and display processors. The uVax simulations receive/send information from/to the multiport memory and 1553 bus.

(3) VAX 8650 used for aerodynamic simulation (airframe), visuals and coordinate conversions. This VAX maintains a high-fidelity aerodynamic model of the F/A–18. The visual process reads and processes incoming "flat earth" data from the entity table in Multiport Memory. The coordinate conversion process performs transformations to/from DIS world coordinates and MFS simulator flat-earth coordinates. This VAX communicates to the Avionic Simulations uVAX (through multiport memory) and to the GE COMPU–SCENE IV.

(4) Multiport memory providing a common data link (shared memory) to avionics and flight dynamics models.

(5) GE COMPU–SCENE IV VIG system to provide for the visual environment in the 40-foot dome surrounding the cockpit and target projector.

(6) uVAX used for communication with the cockpit via MIL–STD–1553 interfaces.

(7) fully functional cockpit of an F/A–18 Hornet.

Secure Integration Simulation Laboratory

The SISL facility is a secure environment for the development, test, and integration of the AIU software. Access is provided to development workstations, AIU hardware, and communications channels for interacting with remote simulations or other AIU devices. The cryptographic equipment allows interaction with the MFS facilities. Interactions between SISL and SITS were constrained to go "through" the MFS connection as described above.

SISL hardware connectivity starts with a local NAV-NET node (T1 tail circuit), which feeds a 56-KBPS tail circuit into the SISL facility. The hardware connection inside the facility, from modem to the laboratory network, is described in the following paragraphs.

Network Hardware Connectivity. Network connectivity consists of all the following equipment required to bring the DIS PDUs to/from the laboratory network:

(1) A NEC Modem configured to operate at 56 KBPS connects the NAVNET circuit to a KG–84A.

(2) A KG–84A point–to–point data cryptographic device connects to the modem by a V.35 to RS–422 cable and a RS–422 to MIL–STD–188C cable. The V.35 connects to the modem while the MIL–STD–188C connects to the "black" (encrypted) connection on the KG–84A.

(3) A TIMEPLEX Minilink unit provides the link between "phone" and computer communications. This unit is connected to the KG–84A "red" (decrypted) connection by an MIL–STD–188C to RS–422 cable.

(4) A RAD REB–1 Ethernet Bridge provides for a dedicated thick ethernet line to the AIU. This unit is connected to the Minilink via an RS–422 cable.

Laboratory Network Equipment. The SISL facility contains:

(1) Bolt, Beranek, and Newman (BBN) Semi-Automated Force (SAFOR) system for generation and control of simulation entities and transmission of the entities on the network.

(2) TSI Low Cost Stealth for display of two- and three-dimensional views of the simulated world.

(3) TSI translator for Simulation Network (SIM-NET)/DIS protocols.

(4) AIU GenTrack unit for generating test entities in either SIMNET or DIS protocols.

(5) Data logger for recording of DIS or SIMNET PDUs to allow playback and/or analysis or testing, demonstrations, and exercises.

NETWORK CONNECTIVITY AND SECURITY

Long-haul network connectivity and security were major issues during the preparation for this POC demonstration. Secured network connectivity between the SITS, MFS and SISL was not established by the time of the POC. The connectivity problems are believed to be the result of KG–84A "strapping" problems. (Each of the four KG–84As needs to be configured or "strapped" before use.)

Originally the POC was to use the secure Distributed Simulation Internet (DSI) network to provide a multipoint connection network with no single point of failure. However, the secure network capabilities were not installed at all three sites by the time of the demonstration.

As an alternative, the U.S. Navy's NAVNET was selected and KG–84As were used as the encryption devices. Because the KG–84 is a point-to-point encryption device, one site must serve as the "hub" of the network and "forward" PDUs for the other two sites. The MFS served as the hub for the POC network. All PDUs generated at the SITS and the SISL were to be sent to MFS; MFS was to send its PDUs to both SITS and SISL. In addition, MFS was to forward all SISL generated PDUs to SITS and forward all SITS generated PDUs to SISL. However, this setup was not successfully installed in time for the POC demonstration.

The problems encountered in getting the network in place and tested were the required long lead time for installing the communications circuits; developing and getting approval of the security procedures and documentation at three sites; generating Memorandum Of Agreements (MOAs), staffing them through the local approval chains and getting the Designating Approval Authority (DAA) to sign off on the network; and getting the required strapping and correct cabling at all three sites as each site has a different modem.

As a result, technicians were still trying to "strap" the 4 KG–84As, at geographically dispersed sites on the day of the POC demonstration. Because of the difficulties of coordinating this strapping effort between three different commands in two different time zones, the secure network was not successfully established. Point-to-point connectivity was successfully established among pairs of sites but not between all three sites simultaneously.

SOFTWARE DEVELOPMENT AND MODIFICATION

This effort required the generation of new software and the modification of existing software. Software for the AIU devices was developed at NCCOSC as enhancements and modifications of software developed during previous efforts. The AIU hardware consisted of two slightly different configurations for the MFS and SITS sites. The software developed was also slightly different. In addition to the AIU software, both MFS and SITS had to develop new software and modify existing software to allow their systems to communicate with the AIU devices.

SITS Software

The existing software was modified to interface with the AIU. These modifications allowed the generation of entities within the RTS based upon Entity State PDUs (ESPDUs) received from the AIU. In addition, the software was modified to output an ESPDU (representing the F–14D) to the AIU. The AIU software was modified to ignore events from the network (Fire PDUs, etc.). The AIU transfers up to two ESPDUs to the SITS system for use in stimulating the RTS.

SITS AIU Software. The AIU reads and writes DIS PDUs to the ethernet port on the Force CPU–40 card; maintains table of entities and their current DIS information, filters entities, transmits selected entities to SITS; ignores all DIS event PDUs; filters out and ignores all non-DIS ethernet packets; maintains SITS F–14D in DIS based on data received from SITS; and tests entity generation.

The interface between the AIU and SITS is maintained by the exchange of data at the rate of four times a second (4 Hertz) via Direct Memory Access (DMA) and DMA emulation. This is implemented by the DR11–W cards. The AIU and SITS read and write data to/from each other's memory via the DR11–W cards. The SITS performs actual DMA transfers while the AIU performs DMA emulation.

The AIU, when interfacing with the DR11–W card, performs byte swapping and floating point conversions. The byte swapping is necessary when communicating data to/from the VAX due to different processor architectures. The floating-point conversions were required to convert IEEE floating-point representation in the DIS PDUs to/from VAX floating point.

All DIS PDUs that are not ESPDUs are ignored. The incoming ESPDUs are first passed through a filter that drops any ESPDUs that are not located within a 70-mile cylinder projected 60 miles in front of the

SITS F–14D aircraft entity. ESPDUs that fall within the filter are then copied into a hash table with the location determined by the ESPDU entity identification field. Since the RTS can accommodate only two targets per run, the AIU sends only the first two ESPDUs it receives to the RTS.

The SITS system transfers an ESPDU for the F–14D to the AIU via the DR11–W interface. The AIU transmits the first ESPDU received from SITS and then dead reckons the SITS entity and outputs a new ESPDU whenever the SITS entity's position or orientation differs from the dead-reckon values by a preset (and modifiable) location and/or orientation threshold. If no positional threshold has been exceeded (i.e., no ESPDU sent out) for 5 seconds, then one is output as required by current convention.

Also, software was built into the AIU to allow generation of a test entity. Through an operator interface, the AIU could be instructed to generate an ESPDU for test purposes. This software would allow the generation of an ESPDU representing an F–14D aircraft entity type and allow modification of the entities location, altitude, course, and speed.

SITS System Software. The SITS system software obtains F–14D airframe state vector data; provides transformations of coordinate, velocity and orientation of the incoming and outgoing ESPDUs; calculates RCS for all target entities; and provides interface processing to the airframe, RTS, and AIU.

The SITS system software consists of the airframe interface, the RTS interface, and the VAX process. The airframe interface software was written to extract the airframe state vector data from the mission computer bus via a *MIL–STD–1553 interface* and send the data to the VAX via a DR11–W interface. The RTS interface was added to the existing RTS and was provided to receive target RCS data from the VAX via Ethernet connection and to use this data instead of the usual "canned" target data that the RTS was initially designed to use. The VAX process ties the AIU, airframe and RTS interfaces together.

The VAX, utilizing modified software from an existing aerodynamic model, provides for all coordinate, velocity and orientation transformations and calculates the target RCS data. The VAX also controls all interface timing and communication between the VAX and the AIU, airframe interface and RTS. The VAX sends and receives ESPDUs to/from the AIU via a DR11–W and receives airframe state vector data from the airframe interface via another DR11–W interfaces and sends the RCS data to the RTS via ethernet "thin" connection.

MFS Software

At MFS, the existing software was modified to interface with the AIU, which allowed the generation of entities within the simulator based upon ESPDUs received from the AIU. The AIU software was modified to send the event PDUs; Fire, Detonation, and Collision. The MFS simulator software will receive the events but not currently process them. In addition, the software was modified to output an ESPDU (representing the simulator) to the AIU. The AIU maintains a table of all entities for the MFS to interrogate and two ring buffers; one containing new entity messages and one containing events, and outputs the simulator's ESPDU on to the network.

MFS AIU Software. The AIU reads and writes DIS PDUs to the ethernet port on the Force CPU–40 card; maintains a table of entities and their current DIS information; passes new entity notifications to MFS; passes DIS Fire, Detonation, and Collision event PDUs to MFS; filters out and ignores all non-DIS ethernet packets; maintains MFS simulator in DIS based on data received from MFS; and generates test entity.

The interface between the AIU and MFS is maintained by data located in shared memory and is implemented by the BIT–3 cards. The AIU and MFS read and write data to a dual port memory maintained on the VME side of the BIT–3 cards. The MFS interfaced with the memory on its BIT–3 card in the same manner as it interfaces with normal VAX memory. The AIU interfaced with its BIT–3 memory card in the same manner as any offboard (nonlocal) VME memory with the exception of data representation.

The AIU, when interfacing with the BIT–3 card, performs byte swapping (necessary when communicating data to/from the VAX due to different processor architectures), and floating-point conversions (required to convert IEEE floating-point representation in the DIS PDUs to/from VAX floating point format)

In the BIT–3 memory, the AIU maintains a table of 1033 "slots" for input DIS entities. Entities are inserted into the table based on a hashing algorithm. When a new entity is received from the network, its entire ESPDU is inserted in the table and the MFS notified by a message in a ring buffer (also in BIT–3 memory). When a new ESPDU is received for an existing entity, the data overlay the existing ESPDU. The MFS can interrogate individual entries in the table whenever it requires data. The AIU dead reckons table entries by updating location and time

stamp information in the table approximately 10 times a second.

Also in the BIT–3 memory is a table maintained by the MFS with 19 slots for MFS entities. The MFS updates these entities at its own processing rate. Three ring buffers in BIT–3 memory transfer event data; one for each direction and one for notification of new ESPDUs to MFS. The ring buffers are maintained as first-in-first-out (FIFO) queue with the oldest message being overlaid in the event of buffer overflow. All DIS PDUs that are not ESPDUs are inserted into the to MFS ring buffer when received. A second ring buffer transfers event PDUs from the simulator to the AIU. The third ring buffer passes indications of new ESPDUs received by the AIU to the MFS.

The AIU transmits an ESPDU at the first encounter in the MFS entity table. The AIU dead reckons the MFS entity based upon the ESPDU and outputs a new ESPDU whenever the MFS entity's position or orientation differs from the dead reckoned values by a preset (and modifiable) location/orientation threshold. If no threshold has been exceeded (i.e., no ESPDU output) for 5 seconds, then an ESPDU is output. Software built into the AIU allows generation of test entities. An operator interface would allow the software to generate ESPDUs representing a user specified entity type at a user specified location, altitude, course, and speed.

MFS Simulator Software. The MFS simulator software obtains incoming event and entity state PDUs from the AIU places them in multiport memory, and provides transformations of coordinate, velocity, and orientation of the incoming and outgoing ESPDUs.

The host process software provides the MFS interface to the AIU, retrieves the incoming DIS PDU data and puts it into the multiport memory, extracts local entity data and events, and places the data into the AIU shared memory. The visual process reads the entity table in the multiport memory, applies coordinate transformations to flat earth, and provides the GE COMPU–SCENE IV with the entity data for target generation. The local entity process performs coordinate transformations on the F/A–18-state vector data and provides this data to the multiport memory, which is read by the host processes.

TEST AND INTEGRATION EFFORTS

Individual pieces were tested separately to the extent possible. Next, the AIU was installed at the MFS site and integration testing with the MFS system was performed. By using the lessons learned at MFS, the AIU was installed and integrated into the system at SITS. However, a communications network had to be established and approved for secure operations before full system integration could be accomplished. The available time expired before the network was successfully used as a transparent encrypted communication medium.

SITS Testing

SITS testing consisted of installing the AIU, establishing DR11–W communications, defining proper data representation (byte swapping and floating point formats), and the sending and receiving of ESPDUs. Interaction of the AIU operating system/CPU board interaction with the Icron DR11–W emulator board resulted in timing problems that took up the bulk of the AIU/SITS interface testing. Proper data representation was accomplished utilizing built-in test DIS PDUs.

To facilitate testing without input from the network, the AIU was modified to generate a F–14D ESPDU, which was injected at the network handler level so as to appear to the AIU/SITS as a real entity. The test ESPDU was successfully displayed on the F–14D APG–71 radar.

A second means of generating an ESPDU was brought online by the Unix Workstation based SIMULIZER. The SIMULIZER generated ESPDUs following a predetermined script, which proved useful for testing consistent fixed flight patterns.

SITS testing also included F–14D "rollout" exercises where the SITS doors were opened and the cockpit was rolled out to allow the radar to actively radiate. Due to close proximity to major airports, many "targets of opportunity" were available for tracking, which allowed for a variety of "real" vs. "simulated" radar operations.

MFS Testing

MFS testing consisted of installing the AIU, configuring the BIT–3 cards, defining proper data representation (byte swapping and floating point formats) and the sending and receiving of ESPDUs. Configuring the BIT–3 required some calls to the BIT–3 corporation. Proper data representation was accomplished utilizing built-in test DIS PDUs.

To facilitate testing without input from the network, the AIU was modified to generate an operator specified entity and allow operator dynamic interaction. The ESPDUs injected at the network handler level, appeared to the AIU/MFS as real entities, which proved to be invaluable in MFS testing as no network traffic was available. Utilizing these test ESPDUs, target visuals were successfully displayed in the simulator dome.

MFS testing also included "wrapping around" the F/A–18 MFS entity with an offset back to the target generator. Thus, the AIU/MFS loop was tested with the target visual acting as a wingman following the F/A–18 movements.

AIU Testing

Both AIU systems, with the exception of correct byte swapping, were extensively tested. A "host" process was designed and coded to run on a separate processor board to simulate/stimulate the SITS DR11–W interface and VAX host process. For the MFS, a host process board and a shared memory board were used to test the AIU against the shared memory, ring buffers, and VAX host processes. Another separate processor board AIU with DIS PDU generation capabilities along with built-in ESPDU test generators were used to generate incoming and outgoing PDUs. "Canned" DIS PDUs were built into each AIU expressly for byte swapping testing.

SISL Testing

Testing at the SISL laboratory occurred in stages:

(1) Final connectivity checks between all systems occurred.
- BBN SAFOR to TSI (SIMNET 6.6.1 protocol)
- GenTrack to TSI (DIS 1.0 protocol)
- GenTrack to Data Logger (DIS 1.0 protocol)
- Data Logger to TSI (DIS 1.0 protocol)

(2) Once all connections were verified, a F–14D was created on the SAFOR workstation and receipt of the PDUs checked at all other devices. This test failed because the TSI translator was not functioning properly.

(3) DIS F–14D aircraft was verified to be sending out to the network but time limitations and security problems precluded a full scale test.

End-to-End System Integration

The goal was to establish a secure network between SITS, MFS, and SISL and then show interaction between all entities operating concurrently. The first step was to establish the secure communications network that would be transparent to the systems using it. Overall systems integrations testing could be performed in accordance with the "Naval Air Warfare Center Aircraft Division (NAWCAD) and the Naval Air Warfare Center Weapons Division (NAWCWD) IGSS Lab Assessment and Procedures." The unsecured network communications were established and verified using the AIU PDU generation facilities at MFS and SITS, the BBN SAFOR PDU generation facilities at SISL, the TSI Low Cost Stealth for display at SISL and SITS, and the MFS dome simulator for display at MFS. Attempts were made to establish secure communications between all three sites using the same equipment to transmit and verify receipt of PDUs. Two-way secure communications were established between SISL and MFS and between MFS and SITS. Three-way communications were not successful, which meant integration testing was not possible.

PROOF-OF-CONCEPT DEMONSTRATION

The HYDY Phase I POC (November 1992 at NAWCWD) consisted of an In-Progress-Review covering both what had been accomplished for phase I, plans for phase II, and demonstrations in the SITS laboratory. Simultaneous radar stimulation with simulated and real targets was the main goal for HYDY Phase I and was successfully demonstrated. The SITS F–14D airframe was "rolled out" on both days of the POC demo to allow the APG–71 radar to actively radiate for detection of live aircraft. The two simulated targets were generated by the SITS AIU and the SIMULIZER.

The first day rollout was marred by a loose 1553 bus connection at the airframe. The bad connection caused noise on the line that wreaked havoc with the interface to the TMS (the program that "flies" the F–14D airframe), and the RTS. These programs would not run long due to lack of stable data from the frame. Eventually, a simulated target successfully injected into the radar receiver resulted in the track displayed on the Radar Intercept Operator (RIO) console.

The second day rollout was more successful. Simulated tracks (two) along with real aircraft were tracked on the RIO console. The simulated tracks were run through a variety of course and speed changes (altitude was not changed). The live aircraft flew "race track" patterns with a long leg coming in off the ocean directly at the SITS laboratory. This flight path, repeated at regular intervals, made it possible to generate a simulated entity that appeared to be flying with the live aircraft and showed the simultaneous detection and tracking by the F–14D radar of both live and simulated aircraft. The demonstration showed no detectable difference between the radar returns of a real aircraft and a simulated aircraft.

The lack of a secured line prevented the MFS dome simulator from providing a manned simulator to stimulate the SITS. The network demonstration

was to have the two facilities, SITS and MFS, "fly" against each other. An example scenario would have put the MFS's F/A–18 cockpit BVR in front of the SITS F–14D airframe with a closing course for a fly by. The F–14D would pick up the F/A–18 as a track on its radar and the MFS would visually display the F–14D when the aircraft came within visual range. As it turned out, both sites had to fly against locally generated AIU DIS aircraft entities. The AIU provides the DIS network compatibility required for each of the sites and has a built-in test function that allows them to generate a variety of DIS entities.

FUTURE EFFORTS

Once the secure communications network is fully functional, the testing and integration will be completed. Work will continue toward building a more robust AIU by using the lessons learned during this effort and research in other areas.

The effort to interface with the F–14D RADAR system will continue with the development of an Airborne RTS (ARTS). This effort will reduce the size of the current RTS and combine the functionality of the AIU into the ARTS hardware suite. The airborne version of the AIU will be modified to accept input from a radio receiver vice an ethernet input. The PDUs received by the radio will be communicated to the ARTS via a 1553B bus. The content of the ESPDUs will be modified because of the limited bandwidth of the transmission hardware. Current plans call for the PDU structure to reflect the design put forth in "Analysis of DIS Protocols for DARPA'S HYDY Project." The generation of the ESPDU representing the live aircraft will be done by a ground station using current Tactical Aircrew Combat Training System (TACTS) range ground station technology and in the air by the airborne AIU. The ground station will serve as an AIU for airborne entities outputing full DIS ESPDUs for the aircraft, filtering received PDU traffic, formatting PDUs for transmission to the aircraft, and conveying the PDUs to the radio for transmission.

In parallel with the above effort, the secure network will be established. The three sites will be integrated and used to perform data latency testing to determine the effects of transmission delays over long distances when using high-fidelity simulations. This may result in further changes or enhancements to the AIU to mitigate any deleterious affects of transmission delays.

REFERENCE

"Military Standard Version 1.0 (Draft) – Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation," Institute for Simulation and Training, University of Central Florida, October 1992.

ACRONYMS

AIU–Advanced Interface Unit
ARPA–Advanced Research Projects Agency
ARTS–Airborne RTS
BBN–Bolt, Beranek, and Newman
BVR–Beyond Visual Range
DAA–Designating Approving Authority
DIS–Distributed Interactive Simulation
DMA–Direct Memory Access
DSI–Defense Simulation Internet
ECM–Electronic Counter Measures
ESPDU–Entity State PDU
FOV–Field-of-View
HYDY–Highly Dynamic Vehicles in a Real and Synthetic Environment
IF–Intermediate Frequency
IGSS–Intelligent Gateway/Scaleable Simulation
IPR–In–Progress–Review
KBPS–Thousand Bits Per Second
LAN–Local Area Network
MBPS–Million Bits Per Second
MFS–Manned Flight Simulator
MOA–Memorandum of Agreement
NAVNET–Navy Network
NAWCAD–Naval Air Warfare Center Aircraft Division
NAWCWD–Naval Air Warfare Center Weapons Division
NCCOSC–Naval Command, Control and Ocean Surveillance Center
PDU–Protocol Data Unit
POC–Proof-of-Concept
RCS–Radar Cross Section
RDT&E–Research, Development, Test and Evaluation
RF–Radio Frequency
RTS–Radar Target Stimulator
RWR–Radar Warning Receiver
SAFOR–Semi–Automated Forces
SIMNET–Simulation Network
SISL–Secure Integration Simulation Laboratory
SITS–System Integration Test Station
STRICOM–Simulation, Training, and Instrumentation Command
TACTS–Tactical Aircrew Combat Training System
TMS–Test Management Station
TSI–Technologies System Inc.
VAX–Virtual Address Extension
VIG–Visual Image Generator
VME–Versa Modula Europa
WAN–Wide Area Network

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Forward

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This year's papers are presented in six tracks.

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Education, Instruction and Training Methodology
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Modeling and Simulation
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The Conference Committee listed on the following pages devote a great deal of time and effort to make this conference a success and they have my sincere appreciation. Each year we try to present innovative approaches and solutions to current problems. Please share your ideas for future conferences by completing the forms provided in each session.

On behalf of the entire committee we hope you enjoy the conference.

Judith Shellnutt-Riess

Judith Shellnutt-Riess
Program Chair